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STRENGTHENING PURCHASING AND SUPPLY CHAIN MANAGEMENT AT TOYOTA: A LECTURE BY HIROAKI KODA[1]

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Abstract
This chapter reproduces a lecture given at the University of Tokyo in 2015 by a general manager at Toyota who was a central figure in the inter-industry support team for the recovery of a major semiconductor producer that was severely damaged by the 2011 Tohoku Earthquake. The lecture also describes how Toyota subsequently created RESCUE, an information database that is used to increase the speed of the company's first response to disasters, and otherwise strengthened its purchasing and supply chain management systems based on the lessons it learned from its experience coping with the wide-reaching disaster caused by this huge earthquake.

Keywords
Shock, Resume operations, Semiconductor devices, TNGA, Toyota way, Respect-for-people principle, Genchi genbutsu principle, Recovery efforts, JAMA, Visualization, Infrastructure recovery, Business continuity management, Fujitsu, High-risk, Thailand, Tianjin, China

INTRODUCTION

Ability to Recover and Ability to Substitute

In the aftermath of the 2011 earthquake and tsunami off the Pacific coast of Japan, there was a wide-ranging discussion among firms, academics and government officials about how firms can recover when their manufacturing systems and supply chains are disrupted by a large-scale disaster. Some of the suggestions put forward during the discussion were that firms should store buffer stocks of components needed for their manufacturing operations and utilize these after disruptions until the supply chain is restored, or that they should build identical assembly lines in two geographically different locations in order to avoid the risk of supply chain disruptions if and when a disaster strikes. In other words, these suggestions called for an increase in inventory and surplus capacity as a measure against natural disasters.

However, this sort of thinking tends to ignore another problem, which the Japanese manufacturing industry is facing, namely the strong global competition mainly affecting export-oriented firms. If Japanese firms focus only on the robustness of their business by increasing their buffer stocks and surplus capacity to avoid the risks associated with natural disasters, then they may be in real danger of losing their international competitiveness and their very survival may be at stake. Disasters strike when least expected, and yet competition is here every day. From a purely historical perspective, it can be said that the 2011 earthquake was the first large-scale natural disaster that hit a broad area in a developed industrial nation, with serious implications for global competition.

Thus, influenced by the psychological shock of the huge damage dealt by the earthquake, discussions in Japanese society tended to be biased toward preserving the robustness of industrial systems. However, over time, the implications of global competition were taken into account and many began to call for a balance between robustness and competitiveness.

For example, as an alternative to having backup productive capacity and increased buffer stocks, it has been suggested that firms employ “virtual dual sourcing” in order to speed up the recovery of their manufacturing facilities, aiming for full recovery in two or three weeks after a disaster (Fujimoto 2012, Fujimoto & Park 2014). This means that, by possessing portability of design information (i.e., the ability to quickly transfer critical design information to alternative assembly lines away from the disaster area), firms can ensure the robustness of their manufacturing operations without having to duplicate assembly lines.

For virtual dual sourcing to function properly, firms need to improve their ability to recover damaged equipment and transfer design information, both of which require considerable effort and preparation. If a disaster occurs, firms need to be able to immediately estimate the required stock of each product and the time needed to restore their assembly lines. Then, based on how quickly normal production is expected to resume for each product, they can either continue to manufacture in the disaster area or transfer dies, jigs and tools, as well as engineering drawings, to alternative production locations. In this way, it is possible to resume operations in the disaster area or away from it before the buffer stock of each product is depleted, with the effect of minimizing supply chain disruptions.

Of course, depending on the condition of their manufacturing systems and on their organizational capabilities, firms may, in certain cases, be forced to seek alternative solutions, like renovating their inventory management system, introducing common parts, duplicating assembly lines or transferring production facilities overseas. Nevertheless, the decision to adopt any of these solutions should be aimed at improving global competitiveness and not only robustness as a way to respond to disasters. With regard to improving response to natural disasters under the conditions of global competition, precedence should be given to strengthening firm capabilities (capability building) over simply increasing buffer stock.

So, in order to ensure a balance between production system competitiveness and robustness, it is important to know what capabilities firms need to build as a means of preparing for large-scale natural disasters. From the perspective of virtual dual sourcing, these capabilities allow firms to: swiftly recover damaged production lines and resume operations in the disaster area; quickly transfer production (design information) to alternative locations; and promptly build an optimal full recovery plan considering the previous two activities.

The fire at Aisin Seiki in 1996 (Chapter 5 in this book), studied by Nishiguchi and Beaudet (1998, 1999), and Kaneka's transfer of operations from the Kashima factory to the Takasago factory in the aftermath of the 2011 earthquake (see Chapter 1), investigated by Fujimoto (2012), are two examples of production being transferred to alternative locations. On the other hand, Whitney et al. (2014) analyzed what happened at the Riken piston production facility in Niigata Prefecture after the 2007 earthquake (Chapter 4), which is a case of swift recovery of the damaged equipment in the disaster area. Yet, the aftermath of the 2011 earthquake provided one of the best-known cases of production recovery in an area hit by a disaster, namely that of the semiconductor and in-vehicle microchip production facility of Company R, which was the global supply base for that firm.

Therefore, listening to the story of someone who had a central role in the recovery process of that facility's production line for semiconductor devices is of great importance and should be a valuable point of reference for future disaster prevention measures. The person in question is Mr. Hiroaki Koda from the Toyota Motor Corporation and this chapter reproduces the content of a lecture that he gave in 2015.

Background of the Lecture by Hiroaki Koda

This chapter reproduces and provides contextual background to a lecture given by Hiroaki Koda, general manager of the Purchasing Planning & TNGA (Toyota New Global Architecture) Promotion Division of the Purchasing Group at the Toyota Motor Corporation, during the Autumn Conference of the Japan Association for Evolutionary Economics, which was held at the University of Tokyo on September 20, 2015. Efforts have been made to reproduce the lecture as accurately as possible. Mr. Koda was a central figure in the inter-industry support team assembled to help Company R, one of the top producers of semiconductor devices in Japan, recover after the 2011 Tohoku Earthquake.

The lecture describes the steps taken by the Toyota Motor Corporation to support Company R and strengthen its purchasing system with regard to supply chain management. This comparatively narrow topic was selected because time constraints would not allow an in-depth explanation of all aspects of Toyota's purchasing system. Moreover, it was thought that hearing the experience of someone involved in the recovery process after the disaster would be particularly helpful to understand the key elements of Toyota's purchasing system that are related to disaster recovery. In hindsight, this was the right decision, since Mr. Koda was able to present the case in a systematic manner. The first part of this chapter includes an outline of Mr. Koda's career and information about the history of Toyota's supply chain. After that, the support provided to Company R during its recovery is illustrated in detail.

The minutes of the lecture were created based on each author's notes, and the combined document was checked, corrected and approved by Mr. Koda. Some parts could not be made public, but this does not diminish the informational value of the account.

The lecture is divided into the following six sections:

1. Outline of Mr. Koda's career and Toyota's business
2. History and characteristics of Toyota's supply chain
3. Lessons from past natural disasters
4. Recovery support provided to Company R
5. Preparation for future natural disasters
6. RESCUE (REinforced Supply Chain Under Emergency) supply chain information system

The chapter closes with a brief summary of the lecture.

LECTURE

1. OUTLINE OF MR. KODA'S CAREER AND TOYOTA'S BUSINESS

Mr. Koda graduated from the Faculty of Law at the University of Tokyo in 1989 and joined the Toyota Motor Corporation, spending most of his career in jobs related to parts procurement. First he was assigned to the purchasing department (*Koubai-bu*), then he was secretary to a vice president of Toyota, and he also spent three years in the manufacturing research center (*Seisan-chosa-shitsu*), where he worked on issues related to the Toyota Production System (TPS). At the time of the global financial crisis of 2008, he returned to the purchasing department and supervised Toyota's production innovation activities, which would eventually lead to the new automobile platforms known as TNGA (Toyota New Global Architecture). When the 2011 earthquake hit Japan in March, he became the leader of an inter-industry support team whose goal was to help the recovery of Company R, one of the biggest semiconductor makers in the world. He was also a member of a similar team in Thailand, assisting authorities and firms in their efforts to recover from heavy floods in the summer of 2011.

In the next section, a summary of Toyota's history and characteristics of Toyota's supply chain in Japan is presented, while Section 3 focuses on the lessons learned from past natural disasters, on the basis of which the RESCUE supply chain information system is later illustrated. The attention of the general public and of the media tends to be drawn to the information system itself. Yet, according to Koda, the history and characteristics of Toyota's supply chain, as well as the lessons learned from past experiences, are vital since such underlying factors represent the real strength of Japan's manufacturing philosophy.

Toyota Motor Corporation's mission is to contribute to society by producing automobiles. The firm has more than 300,000 employees, including those who work in the company's subsidiaries. Its headquarters and main production facilities are in Aichi Prefecture. In total, Toyota has 12 plants in Japan, including those of four subsidiaries in Northern and Central Japan and on the southern island of Kyushu. Moreover, a substantial portion of its vehicle assembly operations is located overseas, with 52 production facilities in 27 different countries.

2. HISTORY AND CHARACTERISTICS OF TOYOTA'S SUPPLY CHAIN

2.1. Characteristics of the Automotive Industry and Automotive Procurement

There are three main general characteristics of the automotive industry that influence automotive procurement. The first general characteristic is that modern automobiles consist of about 20-30,000 components, which requires an extensive and complex supply chain. The second general characteristic is that they have integral product architecture; therefore, the development of new products in the automotive industry calls for extensive collaboration with suppliers. The third general characteristic is that model lifecycle is long, generally around four or five years. This means that long-term business relationships with suppliers are beneficial for OEMs (and for suppliers), since certain components may have to be supplied for up to 15 or 20 years. Consequently, in the automotive industry relationships with suppliers are of great importance, as is their participation in the development of a new product from the very early stages.

2.2. The DNA of Toyota

The DNA of Toyota can be traced back to October 10, 1935, when Sakichi Toyoda formulated Toyota's mission statement. It reflected the main aspects of his credo, namely industrial patriotism, compassion and friendship, teamwork and contribution to mankind. Later, in April 2001, the Toyota Way was formulated, providing an explicit and systematic description of Toyota's managerial beliefs and values, which had been largely transferred only tacitly until then. The Toyota Way was created to help the company diffuse its beliefs and values into its global organization.

2.3. The DNA of Toyota's Purchasing System

The basic principle of Toyota's purchasing system can be described as co-prosperity with suppliers, and its origins can be found in the purchasing regulations written by Kiichiro Toyoda in 1939, which state that supplier factories must be regarded as branch factories (i.e., an upstream extension of Toyota's own production facilities). The goal of the purchasing system should not be the procurement of cheap components. Instead, mutual efforts should be made to boost the productivity of supplier plants and improve the quality of their output. Toyoda's regulations also assert that cost reductions must be reflected in the purchasing price. The guidelines laid out in these purchasing regulations have been followed since then.

In purchasing, the respect-for-people principle of the Toyota Way stipulates that suppliers are Toyota's partners and must be respected, and that relationships of mutual trust must be established. This also implies teamwork, two-way communication and a sense of unity between Toyota and its suppliers. On the other hand, the "wisdom and *Kaizen*" principle of the Toyota Way expresses the idea that improvements in quality, technology, and efficiency should be made together with suppliers, as a single organization. This principle is also closely related to a key concept of TPS, namely *genchi genbutsu*, which suggests that data collection and decision making must be conducted in the place where the work is actually done.

Two specific examples of how the Toyota Way in purchasing is diffused in Japan are Kyohokai and Eihokai, two associations that together total more than 300 firms (mainly suppliers) whose goal is to develop solid relationships with Toyota through a wide variety of activities based on an open partnership. In addition to these organizations and as a measure to promote self-supporting endeavors, every year Toyota sets improvement targets related to safety, quality, cost reduction, etc., after discussions with the top management of each supplier member, and prestigious awards are given to the firms that have made significant efforts in pursuing the assigned targets. Toyota also conducts collaborative problem-solving activities with its suppliers with the objective of improving quality and reducing costs. Moreover, the Toyota Way has expanded internationally over the years and organizations similar to Kyohokai and Eihokai have been established abroad.

To conclude, the history of its purchasing system shows that Toyota has established a solid supplier base originating in Aichi Prefecture, has built long-term, strong relationships with its suppliers relying on mutual support and trust, and has expanded its basic purchasing system to overseas subsidiaries and suppliers. Therefore, it can be said that Toyota and its suppliers are held together by a strong and long-lasting bond, which enables them to act as a single entity.

3. Lessons from Past Natural Disasters

3.1. Comparison between the Tohoku Earthquake and Other Emergencies

Even before the 2011 Great East Japan Earthquake that occurred in the Tohoku region of Japan, Toyota and its suppliers had cooperated in order to respond to emergencies and provide support to affected business partners in several other natural disasters, such as the 1995 earthquake in Kobe, the 1997 fire at Company A, the 2000 flood in Nagoya and the 2007 earthquake in Niigata. However, in these cases, most of the affected firms were first-tier suppliers and the disaster area was relatively small. In contrast, the Tohoku earthquake hit a significantly larger area and most of the affected firms were second- or lower-tier suppliers.

For example, the Kobe earthquake affected only 13 supplier facilities, while the Tohoku earthquake caused 659 supplier facilities to suffer varying degrees of damage. Also, Toyota relied heavily on a certain number of lower-tier suppliers in the Tohoku region for the procurement of some automotive components, so the disruptive effect of the earthquake on the supply chain was considerably stronger than in past disasters. The semiconductor manufacturer described in this chapter is one of these key suppliers and, unlike previous natural disasters, the consequences of its production being disrupted were felt not only domestically but also globally.

3.2. Recovery Efforts

Toyota's basic policy in times of emergency is to help people, communities, and the restoration of production operations, in that order. Therefore, Toyota's first response is to send humanitarian aid to the disaster area, and then move on to restoring normal production operations in disrupted facilities. Also, in accordance with the *genchi genbutsu* principle, Toyota leaves all decisions to the employees of the affected facilities, who best understand what needs to be done, without any interference from headquarters.

Immediately after the earthquake in Tohoku, Toyota sent 60 employees—a number that was later increased to 140—to help distribute 86 eleven-ton truckloads of goods supplied by firms from the Toyota Group. After this initial humanitarian aid, Toyota continued to contribute to the recovery efforts made by the local communities and the automotive industry.

For the restoration of normal production operations, Toyota set up disaster response headquarters and began collecting information at once. The first priority was to analyze the condition of the entire supply chain and find out the lack of which automotive components would have the biggest disruptive effect. It was understood that there were approximately 500 components whose supply was severely impaired, with no certain recovery dates. Owing to the effort made by the whole company to implement the necessary countermeasures, at the end of March (the disaster occurred on March 11) it became possible to resume operations in some facilities. In April operations were resumed in all facilities and in September the pre-disaster level of production was achieved in the affected region.

The basic principle was to prioritize the recovery of the affected production facilities, since the livelihood of the workers depended on them. When that proved to be too difficult, then production was transferred to other facilities of the same supplier. If that was also too difficult, then efforts were made to develop substitute components or change suppliers. Achieving shorter production lead times was never made a priority.

4. RECOVERY SUPPORT PROVIDED TO COMPANY R

4.1. Company Overview and Damage Suffered

Company R was established through the merger of the semiconductor divisions of three major Japanese firms. At the time of the disaster, it was one of the top microcomputer makers in the world, with a 30% share of the global market and a sizable share of the market of in-vehicle microcomputers.

One of the most heavily affected facilities of Company R was in Naka, Ibaraki Prefecture, where wafers were produced using the latest technology. A wafer is a thin slice of semiconductor material on which electronic chips are installed and, at the Naka facility, it was produced as discs in two diameters: 300 mm and 200 mm. The facility was quite large and, in the aftermath of the earthquake, it was not clear where to begin with the recovery process.

Regarding the magnitude of the disaster in Ibaraki, the first earthquake, which occurred at 2:46 pm on March 11, had seismic intensity (Japanese seismic scale) of six-upper and the second earthquake, which occurred at 15:15 pm on the same day, had seismic intensity of six-lower. It was the second earthquake that severely damaged the Naka facility. The earthquakes also caused large cracks on nearby roads.

In the Naka facility, a high voltage cable fell down, crushing an acid exhaust duct (semiconductor plants use large amounts of acid) and damaging a tank containing acid. Fortunately, the acid accumulated in an underground pit and did not leak into the surrounding environment, although it corroded approximately 150 chemical pumps. The earthquake~~s~~ made holes in the walls of the building housing the machinery, which had to be covered with vinyl sheets. The roof and the walls of the clean room, which was supposed to have very low levels of environmental pollutants, collapsed too.

The first obvious tasks were to restore the infrastructure of the facility, including the building housing the machinery, and to repair the expensive high-precision equipment. However, the estimated time required to do so, calculated by Company R based on the shortest start-up time achieved in the past, was one year. Lead times in semiconductor production are very long since it takes between three and four months to manufacture complete products from the wafer and, as mentioned, in the current condition of the facility, the lead time was expected to be more than a year. This also meant that many firms relying on semiconductors for their products might end up going bankrupt, so something had to be done urgently in order to avoid the total collapse not only of Toyota but of the global manufacturing industry as well.

4.2. Infrastructure Recovery: Beginning of Support

Initially, it was important to understand how to restore the infrastructure quickly, repair the clean room and put the equipment back in order. For that purpose, an inter-company team was assembled from members of the Japanese Automobile Manufacturers Association (JAMA), who received permission to travel to the disaster area from the Ministry of Economy, Trade and Industry. However, because of bottlenecks, support to Company R began only two weeks after the disaster.

Also, when the final approval for the dispatching of a support team was received from Company R, it was decided that two or three people from each automaker and seven people from Toyota would join the team, for a total of 17 people. Toyota sent seven experts because a specialist team was needed consisting of people who understood the production process in semiconductor plants and would know how to fix electricity, water and gas supply lines, buildings, production equipment, as well as people from purchasing and production control. As for Company R, only about 200 people from the headquarters were able to participate in the recovery process, while the rest, approximately 2,000 employees, had to return to their homes and help their families, due to the fear of aftershocks.

The headquarters of Company R were located in Tokyo, but the recovery team operated in the disaster area. In addition to the specialists from the automakers, the team consisted of experts sent by firms specializing in the fields of construction, clean rooms, air conditioning, chemicals, water sewage, and six other firms.

Later, additional firms joined the inter-industry support team, for a total of 60 firms. However, the above-mentioned decision by Company R to accept only two or three people from firms other than Toyota was an obvious expression of opposition and, in fact, during the first few days the team was met with a cold attitude. Therefore, the first priority was to gain the trust of Company R and, since most of the team members came from firms that competed with each other, team integration and unification were at the top of the agenda too. In fact, a similar situation had occurred during the recovery efforts at the time of the 2007 earthquake in Niigata Prefecture, with some team members asking that priority be given to recovery of production lines that sent products to their own facilities. This time, however, such behavior was not tolerated from the beginning.

Another problem was that a large portion of the recovery work depended on equipment manufacturers, which required extensive cooperation as well as coordination among them. Therefore, it was vital to ensure that the team worked as a single body, extending beyond industry boundaries and eliminating narrow company interests.

Many members of the support team, including Mr. Koda, were visiting a semiconductor plant for the first time and did not know much about the production process in such facilities, so they had to get acquainted with basic safety precautions. The clean room contained a large number of hazards and in other areas of the facility there was the danger of poisonous gas leaks, liquid chemical leaks (strong acids like hydrochloric acid, sulfuric acid or hydrofluoric acid), electric shocks of several thousand volts, etc.

Hydrofluoric acid was particularly dangerous because it is colorless and transparent, making contact with it difficult to notice, but the severity of burns caused by it may lead to fatalities. Therefore, safety was given first priority and arrangements were made to build a temporary medical center, where people could be treated if they came into contact with dangerous chemicals.

In addition to these hazards, there was always the danger of aftershocks. Tremors could be felt around every two hours and sometimes aftershocks with seismic intensity of four or five occurred. In such cases, which often required temporary evacuation, recovery work could resume only after safety had been confirmed. Furthermore, in order to verify that there was no danger, the air in the clean room had to be ventilated, which is unthinkable under normal conditions.

Visualization of problems, something that Toyota is good at doing, was also carried out, and maps showing all hazards were created and placed in several spots. Since a large number of team members were visiting a semiconductor plant for the first time, comprehensive explanations of the hazards that each piece of equipment posed were prepared and displayed. Moreover, in order to provide early warning of any potential danger, several thousand hazardous chemical detectors and other safety devices were installed.

4.3.Infrastructure Recovery: Strategy Definition and Team Integration

The general strategy was to set high targets and to attempt to achieve them by unifying the team toward common goals. For that purpose, several slogans, calling for swift recovery, cooperation and solidarity, were displayed in the central office of the team, in order to serve as the foundation of the team’s decisions and activities.

One of the notions expressed in the slogans was that time was of great importance and always had to be taken into account when making decisions. Toyota is famous for being economical and for using only the necessary resources in the necessary amount; yet, in an emergency, time cannot be wasted verifying what is needed. So, for example, if ten machines were thought to be out of order, instead of spending time checking which machines were actually out of order and purchasing replacements only for them, the team would purchase ten machines from the very beginning.

The slogans were also meant to promote team spirit and involvement in the recovery work and to make all members realize that everyone in the team had a leading role in what they considered to be saving the world manufacturing industry.

Also, unification and visualization of the schedule were vital to ensure that each member understood what recovery work had to be completed by what date. Thus, it became easier to see which tasks could be performed simultaneously and understand where bottlenecks might occur.

The organization of the team changed based on what the situation required and this was indicated with post-it notes stuck onto the team's organizational chart. New people joining the team were assessed based on their abilities and deployed immediately. In March there were only 60 members from JAMA but, at peak time, their number increased to more than 200. In order to make certain that they could be easily contacted, their business cards were posted on a wall.

Regarding information sharing, the team met once every morning (8:30-8:50 am), then there was another meeting with representatives from Company R (9:00-9:30 am), as well as an afternoon meeting (16:00-17:00). Building mutual trust among team members was an important goal, toward which significant progress was made at the time of the inspection of the circuit breaker panels in the facility. Company R had requested several hundred electricians to be provided by JAMA but, since accommodation capacity and food supplies were limited, it was decided to carry out the inspection of the circuit breaker panels with the ten electricians who had already arrived. Surprisingly, they were able to complete the inspection in less than a day, which was a success that boosted the morale of the entire team.

The members of the team had come from all over Japan, working 24 hours a day in three shifts. During the peak period of infrastructure recovery, 2,500 man-days were spent by the team on recovery work and, together with the recovery effort of Company R, this figure went up to 5,000 man-days. Nearby cherry trees had to be cut down to free up extra car parking space and provisional personnel rest areas had to be built.

Also, in order to ensure that the team could concentrate on its tasks and work in a safe environment, each participating firm sent specialists who created groups responsible for general affairs and safety, greatly facilitating accommodation, food supply, and transportation.

4.4. Infrastructure Recovery: Visualization of Bottlenecks and Swift Problem-Solving by the Special Task Team

Preliminary calculations had shown that the recovery of the facility's infrastructure would require two and a half months. Nonetheless, this goal was actually achieved within about ten days, due to bottleneck visualization and the creation of a special task team able to solve problems swiftly.

One example was the recovery work on a large acid exhaust duct. In this case, the bottleneck was caused by the fact that, as the duct had been extended multiple times in the past, its engineering drawings were not in the factory. In order to solve the problem, representatives from 11 duct manufacturers were called. They assessed the damage and, based on their observations, recreated the original drawings of the duct in just three days. The repair work, for which parts were procured internationally, was carried out by six firms and completed in one week.

Another example was the procurement of 150 chemical pumps. These were special machines with long production lead times and the materials team leader was engaged in the process of negotiating with a trading firm (a business partner of Company R) to procure replacement pumps. To shorten the lead times, it was decided to consult with chemical pump manufacturers directly in order to find out why production would take so long.

The following episode demonstrates the measures taken to deal with the problem. One of the team members, who had learned the basics of TPS from Mr. Koda during their time together at Toyota's manufacturing research center, was sent to a pump manufacturer in Tokyo. Mr. Koda gave him a list of pumps that had to be procured, saying that their delivery usually took two weeks and asking him to deliver them on the following day. When the team member visited the pump maker, he discovered that they had insufficient amounts of some of the components used in building that specific type of pump, which greatly delayed the manufacturing process. Pressed for time, he borrowed the blueprints of these components and brought them to his firm, where he had the missing components manufactured and carried back to the pump maker, which managed to assemble the required pumps and deliver them on the following day.

The recovery of the Naka facility's infrastructure was completed in ten days and the next step was the recovery of the semiconductor manufacturing equipment.

4.5. Recovery of the Semiconductor Manufacturing Equipment

Several semiconductor equipment engineers were needed for the recovery work because the manufacturing of semiconductors is complex and sophisticated, involving numerous microfabrication processes. The precision required to conduct 40 nanometer work on a 30 centimeter disc is equal to the precision required to draw multiple layers of 4 millimeter lines over a 30 kilometer distance.

In this regard, help came from the Ministry of Economy, Trade and Industry, where negotiations were held with the presidents of semiconductor equipment suppliers, who agreed to dispatch technical personnel. These engineers, sent by 39 firms from Japan and the US, spent a total of 18,000 man-days on the recovery work, assembling special teams for each manufacturing process.

The exchange of information was managed using a large room where members from different firms wearing uniforms of different colors were gathered, with the goal of speeding up the decision-making process by reporting only unsolved problems. The manufacturing of semiconductor devices involves approximately ten processes and, in order to visualize progress in the recovery, the schedule for each process was displayed on a wall in the large room.

At the same time, production start-up plans and order of precedence for products were determined. The major policy decision was to give precedence to products characterized by a comparatively high degree of difficulty in terms of production quality and technology. It was thought that solving the difficult problems first would make the later production start-up phases run smoothly. Also, all product information was codified to make sure that nobody gave precedence to products needed by their own firm.

The products exhibited considerable diversity, consisting of 14 types of 200 mm wafers and 13 types of 300 mm wafers, for a total of 27 types, and each required 800-900 semiconductor devices to be installed on them. So, in order to avoid confusion, timetables for each process and allotment schedules for semiconductor devices were created, showing in detail how many weeks would be needed for the complete recovery of each device.

One example of a device whose recovery was accompanied by significant problems was the baking device for semiconductor coating. Numerous measures were taken to ensure that its recovery would be achieved on time, such as: urgent purchasing of new components and use of existing components that had survived the disaster, transfer of excess equipment from other firms and purchase of used machinery, as well as cancellation of orders for certain products. The firms that provided equipment were in turn helped by Company R when their own facilities in Thailand were damaged by floods in the summer of 2011.

The recovery of the production line for semiconductor devices continued at a fast pace and on the 13th day it was already possible to begin production of the first lot. A simple opening ceremony was held to celebrate the rapid recovery and to increase the motivation of all those who had contributed to it. Also, Company R decided to give names to the first production lots, calling the first 200 mm lot "Bond," while the first 300 mm lot was given the name "Gaia," after the ancient Greek goddess of the Earth, symbolizing a new beginning. At that point, it was clear that the recovery of the facility would be completed earlier than previously expected, so a press conference was held at Company R, attended by a large number of news agencies.

The work of the support team resulted in full recovery being attained on June 23, approximately six months earlier than estimated at the beginning of the operations. To achieve this significant reduction in lead times, more than 200 people were involved in planning the recovery operations, approximately 5,000 people in the recovery of the facility infrastructure and approximately 3,500 people in the recovery of the production equipment, for a cumulative total of approximately 130,000 man-days until the end of May.

5. PREPARATION FOR FUTURE NATURAL DISASTERS

One lesson that can be learned from the case presented here is that the ability to recover is in fact the ability to solve problems (make improvements). Of course, firms implement measures for business continuity planning (BCP) and business continuity management (BCM) and create documentation based on experience from past disasters. Yet, this preparation may not be enough, since the power of future disasters is likely to considerably exceed what has been anticipated. Therefore, firms must have the ability to train people who, regardless of the gravity of the situation, can make the right decisions by going out and seeing what is happening (i.e., e.g., applying the genchi genbutsu principle). These individuals also need to be good leaders, who are able to inspire others. However, such people can be prepared only through improvement activities aimed at solving the many minor problems that occur every day, so their training has to start at an early stage and well before a disaster strikes.

Looking back on the activities of the support team in the aftermath of the 2011 earthquake, one can conclude that the key to successfully resuming production operations much earlier than expected lies in a type of management possessing three major qualities: heart, technique, and physique (which are incidentally the three qualities of a sumo wrestler). By clinging firmly to the belief that what they were doing was for the benefit of the entire industry and that all team members had a leading role in the recovery operations, and by employing people tempered by their experience in the Just-in-time system, the team was able to overcome the limits of firms and organizations and act as a single body, thus achieving the swift recovery of the semiconductor manufacturing operations at Company R.

6. RESCUE (REINFORCED SUPPLY CHAIN UNDER EMERGENCY) SUPPLY CHAIN INFORMATION SYSTEM

6.1. Supply Chain Survey and Planning

Two of the problems accompanying the recovery efforts in the aftermath of the 2011 earthquake were delayed first response and delayed countermeasures. What caused these problems appears to be the fact that there was no information about the state of the supply chain right after the earthquake occurred and that there were no alternative production sites. Therefore, Toyota decided to conduct a survey of the parts and materials used in the automobile industry in Japan. This meant that information on second- and lower-tier suppliers had to be collected from first-tier suppliers, corresponding to approximately 13,000 firms, with 4,000 component types and 30,000 production sites. The response rate was very high, with almost all suppliers disclosing the requested information, and this success is attributable to the relationship of mutual trust built over the years between Toyota and its suppliers.

The results of this survey helped visualize the dangers of potential supply chain disruptions by pinpointing high-risk components, i.e., e.g., components produced in a single facility or made using special materials or manufacturing processes. The results of the survey also served as the basis to elaborate countermeasures against supply chain disruptions.

In the event of a disaster, key countermeasures involve creating a list of damaged facilities and of the components they produce and drafting response orders giving priority to the abovementioned high-risk components. As of September 20, 2015 (the day of Mr. Koda’s lecture at the University of Tokyo), countermeasure plans covered 97% of all high-risk components. Permanent countermeasures include dispersion of production facilities, improved disaster mitigation capability, standardization and increased component inventory (for certain components only).

In addition, a supply chain database and a hazard map database were created in cooperation with Fujitsu and incorporated into a supply chain information system. This system currently uses cloud-based software provided by Fujitsu and is called RESCUE. The goal of RESCUE is to prevent supply chain disruptions by maintaining information and visualizing potential problems generated by high-risk components. Moreover, in the event of a disaster, the system facilitates quick response to developing situations in a predetermined order of priority.

6.2. Description of RESCUE

RESCUE is a supply chain information database utilized by Toyota and its first-tier suppliers with the goal of increasing the speed of first response to disasters. It is used as follows.

First, before a disaster strikes, the database serves as a means of storing component information and visualizing potential disruption risks along the supply chain. For instance, when the keyword “door trim” is entered into the search engine, all the most recent information provided by suppliers is combined to generate and display a supply chain tree for this particular component. Also, the geographical distribution of the risk associated with each component and facility can be seen on a map. This function incorporates an existing hazard map database (for earthquakes, tsunami and floods) provided by a government institution. Furthermore, components produced in a single facility, special components and high-risk components can be marked with different colors, so information can be displayed in several layers. These high-risk components are the primary targets of disaster prevention countermeasures.

If a disaster occurs, for example an earthquake affecting a large area, a list of plants that may potentially be damaged can be created based on information about their location and business transactions along the supply chain. Earthquake magnitude data are received directly from the Japan Meteorological Agency and can be exported as standard document formats used by Toyota.

In addition, if lower-tier suppliers who do not do business with Toyota directly are affected by a disaster, potential upstream disruptions along the supply chain can be immediately deduced from recorded data on transactions between suppliers from different tiers.

Thus, owing to the use of this database, it is now possible to greatly accelerate first response to disasters—and even more rapid response may be expected in the future thanks to the expansion of the information recorded in the database and better risk management. Also, a similar supply chain risk management system called SCR-Keeper, which is a further development of Toyota's RESCUE system, has already been adopted by other industries and firms, both in Japan and overseas.

6.3. Future Potential

It is worth noting that the RESCUE supply chain system owes its existence largely to the fact that collecting the information recorded in it was made possible due to the relationship of mutual trust between Toyota and its suppliers. Confidential information was released since the suppliers were convinced that it would be beneficial in case of first response to disasters. It has been made certain that such information will never be used to press suppliers into reducing their prices. Also, significant efforts have been made to ensure that the data are accurate and updated, and database maintenance is performed annually as well as before the start of new projects.

Another domestic case that was described to the authors of this chapter, where the RESCUE system proved valuable was during heavy rains in Eastern Japan in 2015. The data in the system were used to identify suppliers facing flooding risks in the aftermath of the heavy rainfall. Fortunately, the supply chain suffered no significant damage and Toyota's efforts were directed toward providing relief to the disaster area.

As for overseas applications of the database system, including Thailand, where floods pose a considerable threat to the local supply chain, risks were identified in ten facilities and measures were taken to counter them. The database was adapted to local needs in Thailand and parts of it were integrated into the SCR-Keeper system, which has been adopted in a number of ASEAN countries.

In Tianjin, China, a Toyota production facility was severely affected by explosions at a container storage station in 2015. 4,700 cars that had already been assembled and were being stored at Toyota's nearby Tianjin vehicle assembly plant were damaged and operations at the plant had to be stopped for two weeks. A number of suppliers to the Toyota facility, including the plant of an American semiconductor manufacturer, which were located within a radius of two kilometers from the explosion, also suffered from the accident.

The Tianjin case highlights one aspect of RESCUE that needs to be improved, which is the fact that the database contains relevant supply chain data for suppliers in Japan only. Comparatively speaking, very little is known about the components made by overseas suppliers and then imported into Japan. In the case of the Tianjin explosions, the stock of components was sufficient to compensate for delayed deliveries caused by the ensuing supply chain disruptions. Nevertheless, the database certainly needs to be expanded to include overseas suppliers, particularly considering that, in principle, Toyota procures components for its overseas assembly operations from local suppliers.

Finally, it ought to be stressed again that the Toyota supply chain management system would not be possible without the existence of a strong relationship based on mutual trust between Toyota and its suppliers. This relationship is built on the grounds of improvement and problem-solving activities carried out together with them. Rapid first response to disasters and damage mitigation are achieved, at least in the case of Toyota, by developing human resources prepared to take a leading role in recovery operations in disaster-stricken areas and by thoroughly understanding supply problems through the accumulation and systematization of knowledge about the supply chain.

Summary

Continuing from the last chapter, here we investigated capabilities, principles, practices and leadership for anti-disaster supply chain resilience at Toyota and its Group, focusing on a lecture given by Mr. Hiroaki Koda, general manager of the Purchasing Planning & TNGA Promotion Division of the Purchasing Group at Toyota Motor Corporation.

As the content of his lecture shows, he played an important role in the inter-industry support team assembled in order to help Company R recover from damage caused by the 2011 Great East Japan Earthquake. The lecture also describes Toyota's capability building process to strengthen its purchasing system and supply chain management over time. Based on lessons learned from past disasters, including the 2011 Earthquake, Toyota created the RESCUE database for quick detection of damaged suppliers. Although this system has attracted significant attention from the mass media, Mr. Koda argues that the real strength of Japan's manufacturing philosophy lies in the history of kaizen and the decision-making capabilities accumulated through past instances of supply-chain disruption and subsequent recovery.

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